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ABSTRACT

Relational responding and peak shift were found to be related. In two experiments, pigeons were trained to make a successive discrimination by either the blackout method of errorless learning or training with extinction. In experiment 1, pigeons trained with extinction learned a circle-sized discrimination more quickly than pigeons trained with the blackout technique. In experiment 2, the results of experiment 1 were confirmed with a more difficult discrimination and the blackout technique was found to produce both peak shift and relational responding in some subjects. The results were tentatively related to Terrace's analysis of discrimination learning. The question is raised as to whether the blackout technique of errorless learning is not in fact a traditional extinction method. (Author)

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University of Pittsburgh

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The Effect of Time Outs to S-

Approaches on Transposition and Peak Shift

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Introduction

Discrimination learning with extinction of responses to the negative stimulus (S-) differs from discrimination learning without responses to S-. After a traditional discrimination has been trained with "errors" (responses to the S-), the point of maximal responding on the generalization gradient shifts from the positive stimulus (S+) to a stimulus on the opposite side of S+ from S-. However, when a fading technique establishes a discrimination without the emission of responses to the negative stimulus there is no peak shift (Terrace, 1964; Grusec, 1968), perhaps because without extinction there is no inhibition (Terrace, 1966a). In fact recent studies demonstrate a gradient for the generalization of inhibition after training with extinction of S- responding, but not after training with no responses emitted during the S- (Terrace, 1966a; Lyons, 1969a).

The generalization of inhibition after discrimination training with errors has also been proposed to account for relational responding. Spence (1937, 1942) hypothesized that for any stimulus on a continuum there is an interaction between a generalized excitation, developed from reinforced responding to the positive stimulus and generalized inhibition, the result of extinguishing responses to the S-. Spence posited that when stimulus

pairs are presented on transposition tests, the algebraic summation of the excitation and inhibition gradients would determine the responses to each stimulus. If the stimuli are properly spaced, relational responding should be obtained on transposition tests. Presumably after discrimination training with an errorless method, transposition should not occur since there is no inhibition.

Both peak shift and transposition could, therefore, result from inhibition. There are several indications of this relationship. Stimulus spacing appears to influence both peak shift (Terrace, 1966b, p. 614) and transposition (Spence, 1937). Honig (1962) found that only subjects who showed peak shift on a generalization test responded relationally on a later transposition test.

The present study investigates the relationship between transposition, the peak shift and the method employed in the original discrimination conditioning to determine whether transposition as well as peak shift is absent after an errorless procedure. Recent studies (Lyons, 1969a, 1969b) have employed a new technique to train an errorless discrimination. Each time the subject approaches the negative stimulus the chamber is darkened thereby preventing unreinforced responses to S-. This technique contrasts with the fading method (Terrace, 1963) where the negative stimulus is originally introduced at a very low intensity and duration, and where the intensity and duration are gradually increased over trials until the final value is obtained. Lyons' blackout technique appears preferable to the fading method, because it can be reliably used with any dimension and errorless birds can have S+ pretraining. Both the blackout technique and traditional discrimination conditioning were employed in the present study to explore the

hypothesis that subjects whose responses to the S- were inhibited by extinction would have an inhibition gradient and therefore would respond relationally on transposition tests and exhibit a peak shift on generalization tests. Subjects conditioned with Lyons' errorless method presumably would not have this inhibition and therefore neither should respond relationally on transposition tests nor show a peak shift on generalization tests.

Method

Subjects

Twelve adult, experimentally naive, White Carneaux pigeons were used. They were all maintained at approximately 80 percent of their free-feeding weights.

Apparatus

The experimental chamber was a modified Grason-Stadler two-key pigeon chamber with two translucent keys, each 1 in. (25.4 mm) in diameter, mounted 235 mm above the floor and 102 mm apart, center-to-center. Each key required a minimum force of 10g for operation. The keys could be transilluminated by white circles of different diameters projected on a black background by an inline projector. Stimuli appeared equally bright to a dark-adapted experimenter. The chamber was located in a darkened room and had a 151 mm x 123 mm window through which the experimenter could observe the subject. A diffuse 7 watt houselight illuminated the chamber. A hopper filled with mixed grain could be made available through a 44 mm x 52 mm opening located 57 mm above the floor. Reinforcement was a 3.75 sec. period of access to the hopper of grain. During the reinforcement cycle, the

houselight and key light were turned off, and a 7 watt bulb directly above the grain was turned on. The chamber was in an air-conditioned room masked by white noise.

Automatic equipment, housed in a separate room, controlled reinforcement contingencies, stimulus changes and recording except that blackouts for the errorless birds were manually initiated by an experimenter.

Experiment 1: Transposition and Generalization to Highly Discriminable Stimuli After Two Methods of Discrimination Training

After a discrimination has been conditioned, the standard transposition test presents stimulus pairs on each trial. Standard generalization tests, however, employ only one stimulus per trial. Therefore, a successive discrimination was trained in a two-key chamber. During training, only one stimulus, S+ or S-, appeared per trial, and the key position of the stimulus alternated randomly over trials. Subjects learned to respond to the larger stimulus (S+) and not to respond to the smaller stimulus (S-) by either traditional discrimination conditioning or an errorless method.

After learning the discrimination, each subject was tested three times. The first and third tests recorded the amount of relational responding to stimulus pairs and showed changes in the pattern of responding with overtraining. The second test presented only one stimulus on each trial, and was used to obtain a generalization gradient unconfounded by the presence of a second stimulus. Since responses were not reinforced during testing, responding was reestablished by separating each test session with a discrimination session.

Procedure

Data were obtained daily from six pigeons. Each session terminated after 50 reinforcements. Table 1 shows the stimuli employed in this experiment.

Stimulus 1 (S-) had a diameter of 0.17 in. (4.3 mm) and each succeeding stimulus increased by a factor of 1.4. Stimulus 2 (S+) had a diameter of 0.27 in. (6.9 mm).

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Insert Table 1 about here

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Preliminary treatment. During the first two sessions, all subjects were magazine trained and were reinforced for each peck on S+ when it appeared on either key. In the third session, and for all subsequent sessions, trials were 30 sec. in duration and separated by a 10 sec. intertrial interval, during which the chamber and keys were dark. Responses in this period delayed the onset of the next trial for an additional 10 sec. During the third session, responses to the positive stimulus were reinforced on a variable-interval schedule (mean interreinforcement time of 30 sec.). The S+ was alternated randomly on the two keys. For the next seven days of training, subjects were conditioned to respond to the alternating positive stimulus on a variable-interval (VI) 60 sec. reinforcement schedule.

Discrimination training. For all birds during discrimination conditioning, negative stimulus trials were introduced and they alternated randomly with positive stimulus trials. Key position continued to vary randomly. For the traditional method subjects, S-39 and S-41, responses to the negative stimulus were never reinforced. S-42, who was started as an errorless subject, was switched to this procedure after failing to learn the errorless discrimination in seven training sessions. This phase of training continued until the total number of responses to the positive stimulus during one session was at least 20 times greater than the number of responses to the negative stimulus.

For the errorless method birds, S-40, S-43 and S-44, the emission of responses to the negative stimulus was prevented by darkening the chamber whenever the subject approached the negative stimulus. This procedure differs considerably from the fading technique employed by Terrace (1964). Pilot work had indicated that the fading technique was not reliable when used with circle-size dimension, however. When the blackout procedure is employed, the negative stimulus is introduced at its full intensity and duration. The experimenter observes the subject, and when the subject makes any movement toward the negative stimulus, the experimenter manually closes a switch which darkens the chamber for 2 sec. Lyons (1969a) demonstrated that when orthogonal dimensions are used for S+ and S- during discrimination training, birds conditioned with this method do not have a gradient of inhibition around the negative stimulus.

In the errorless method each subject was trained with the blackout technique until the total number of responses to the positive stimulus during one session was at least 20 times greater than the number of approaches to the negative stimulus.

Tests of transposition and generalization. After reaching criterion, each subject was tested three times. The first and third tests were transposition tests. The five stimulus pairs were presented in a random order and the number of responses to each member of the pair recorded. Each stimulus pair appeared on 10 trials. The second test presented only one stimulus per trial. Both the order of presentation and key position were randomly varied. This test was used to obtain a traditional generalization gradient. Since responses were not reinforced during testing, responding was reestablished by separating each test with an additional discrimination session.

Table 2 summarizes the daily procedure used with each subject.

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Insert Table 2 about here

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Results

Table 3 shows that the discrimination was quickly conditioned in all subjects except S-42. The subjects conditioned with extinction, S-39 and S-44, reached the criterion on the second day of training. One errorless method subject, S-43, also reached the criterion on the second day of training. The other errorless subjects, S-40 and S-44, reached the criterion in three days. S-42, started as an errorless method subject, failed to learn the discrimination after seven days of training, and was then switched to the traditional discrimination conditioning method. After extinction was employed, S-42 reached the criterion in two additional sessions. The traditional discrimination conditioning method therefore appeared to be the faster training technique.

With the exception of S-42, the total number of approaches to the negative stimulus for the errorless method group was fewer than the number of negative stimulus responses emitted by the traditional method subjects.

On some approaches to the S-, the errorless birds would follow through with a response on the darkened key. The number of these "follow through" responses remained at a value that was less than one-half the number of approaches in all cases.

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Insert Table 3 about here

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Figure 1 shows that most subjects had relatively few relational responses. In Figure 1, the black bars represent the percentage of responses emitted to the larger stimulus within each stimulus pair. During discrimination training, S+ was stimulus 2 while S- was stimulus 1. On new test pairs, such as pair 2-3, relational responding is indicated by the black bar. The responses to the stimulus pair are primarily relational when the value of the black bar exceeds the value of the white bar. On the first transposition test, only one subject, S-39, responded relationally to stimulus pair 2-3. S-39 had been trained with the traditional method. All other subjects responded primarily on an absolute basis on this test, i.e., their responses could best be predicted from an excitation gradient centered at the positive-stimulus value. The negative stimulus influenced the results, however, since there was some relational responding in all cases.

On the second transposition test, relational responding decreased for all subjects except S-42 (Fig. 1). S-42's relational responding increased to stimulus pair 2-3 in the second transposition test. In the discrimination session immediately preceding this test, S-42 more than doubled his criterion number of S- responses. This result may therefore be due to a breakdown of the discrimination.

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Insert Figure 1 about here

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Figure 2 shows the calculated and obtained generalization gradients for each subject. The gradients for tests 1 and 3 were calculated from the transposition tests by summing all of the responses to each stimulus, e.g., the value obtained for stimulus 2 represents the sum of the responses to stimulus 2 for both pair 1-2 and pair 2-3. The gradient obtained in test

2 was from a standard generalization test. Peak shift was found with only one subject, S-42, on his second transposition test. For all other subjects, each gradient is centered at the S+ value and relatively fewer responses are emitted to other stimuli over repeated testing.

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Insert Figure 2 about here

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Discussion

The finding that traditional discrimination training with extinction produced faster learning than an errorless method after equated S+ pretraining has not previously been reported. Previous investigators using the errorless method have tended to employ a fading technique, e.g., Terrace, 1966c; Grusec, 1968. When the fading technique is employed, it is difficult to give extensive S+ pretraining because the negative stimulus must be introduced early to prevent the emission of S- responses (Terrace, 1963).

The failure to obtain peak shift for the traditionally trained birds obscures the solution to the original problem. These results may be related to the ease of the discrimination. Several investigators have reported that greater peak shift is found when the values of the positive and negative stimulus are closely spaced on a continuum than when they are more widely spaced (Hanson, 1959; Thomas, 1962; Terrace, 1966b). Therefore, a second study was performed to investigate the effect of stimulus spacing.

Experiment 2: Transposition and Generalization to Closely Spaced Stimuli After Two Methods of Discrimination Training

Procedure

The procedures were the same as in experiment 1 except for the schedule of reinforcement and stimuli employed. After preliminary training to peck the key, experiment 2 used a VI 30 sec. reinforcement schedule instead of the VI 1 min. schedule of experiment 1. Positive stimulus responses were reinforced on the VI 30 sec. schedule for seven days, after which discrimination training was introduced as in experiment 1.

Table 4 shows the stimuli used. Stimulus 1, the negative stimulus, had a diameter of 0.185 in. (4.70 mm) and each succeeding stimulus increased by 0.035 in. (0.89 mm). The size difference between the positive and negative stimulus was 0.070 in. (.178 mm). In experiment 1 the size difference had been 0.10 in. (2.5 mm). On the transposition and generalization tests, the size difference between adjacent stimuli was also smaller than in experiment 1.

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Insert Table 4 about here

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Results

The number of S- approaches by the errorless group and the number of responses to the negative stimulus by the traditional method group were greater in experiment 2 than in experiment 1, indicating that the discrimination was more difficult. This is also reflected in the greater number of days to criterion in the second experiment.

Table 5 shows that many of the results of the first experiment were also found in experiment 2. The traditional method birds learned the

discrimination in fewer sessions than the errorless method birds. The errorless method generated fewer S- approaches than the number of S- responses produced by the traditional method.

The number of "follow through" responses on the darkened key ranged from a low of 88 for S-53 to a high of 341 for S-51.

Table 5 also shows the average rate of responses to S+ for the training sessions. The rate of response was lower for the errorless method group, with S-51 and S-53 having particularly low rates.

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Insert Table 5 about here

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Most subjects responded on a relational basis to stimulus pairs 3-4 and 4-5 on the first transposition test (Fig. 3). Since stimulus 3 was the S+ value, the negative stimulus was probably having an inhibiting effect. On stimulus pairs more distant from the training values, all of the subjects except S-46 tended to respond on an absolute basis.

On the second transposition test, all of the subjects responded on an absolute basis to stimulus pairs 3-4 and 4-5, and to most of the other stimulus pairs.

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Insert Figure 3 about here

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The generalization gradients (Fig. 4) show that all of the subjects, except errorless subject S-47, showed some evidence of peak shift on the first transposition test. On test two, after an additional day of

discrimination training, there was less evidence of peak shift. By the third test, each subject had a mode of responses at the S+ value, stimulus 3.

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Insert Figure 4 about here

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Discussion

Although peak shift has never before been reported after discrimination training with an errorless method, previous investigators have employed the fading technique during training (Terrace, 1964; Grusec, 1968). The blackout technique has not previously been used to condition a discrimination where the S+ and the S- are on the same continuum. When the positive and negative stimulus are related, inhibition may be built up during discrimination training with the blackout technique, resulting in a peak shift on the generalization gradient. The blackout technique, therefore, seems to share many of the properties of traditional discrimination training. The behavior of the errorless birds during the S- trials supports this view. In the presence of the negative stimulus, many of the birds moved their heads back and forth along a side wall, occasionally looking briefly at the S- and sometimes rushing at the key. This behavior is suggestive of responses to a stimulus which has aversive properties as suggested by Terrace to be established by traditional training. In contrast Terrace (1963) reported that when the fading technique was used to obtain errorless learning, the birds stood passively in front of the key during an S- trial.

Possibly an extinction-like effect resulted from the "follow through" responses just after the S- was turned off. However, the data offer little support since S-47, the errorless subject with no peak shift, had more

"follow through" responses than S-53 who did show peak shift. On the other hand the relatively high S+ rate for S-47 may reflect sufficient excitation to mask a slight gradient of inhibition.

To test the effect of the excitation gradient, two new blackout method subjects (data not shown) were trained with a procedure that produced a high rate of responding to S+. For these subjects, the reinforcement duration was increased to 5 sec. throughout. During two initial training sessions, responses were reinforced on a VI 15 sec. schedule. Following these sessions, the procedure was the same as in experiment 2. When these subjects were tested, both had large amounts of relational responding and peak shift. Variations in the level of excitation, therefore, do not account for the peak shift found with the blackout method.

General Discussion

Peak shift and relational responding on transposition tests are closely related. All subjects in both experiments who showed peak shift on the first transposition test also responded on a relational basis when the S+ value was paired with a larger stimulus. Of the two, relational responding may be a more accurate indication of the inhibition gradient associated with S- than is peak shift. On the first transposition test, all subjects had some relational responses. These relational responses probably resulted from the gradient of inhibition. This inhibition would not be apparent from the generalization gradients alone (e.g., S-41 in experiment 1) since there was no obvious peak shift. The correlation between inhibition and relational responding suggests that transposition may be a fruitful area in which to study the subtle effects of inhibition.

The difference in the amount of peak shift in experiment 1 and 2 is probably due to two factors. In experiment 2, the discrimination was more difficult and the test stimuli more narrowly spaced than in experiment 1. The greatest shift in the mode occurring in experiment 2 was to stimulus value 5, whose diameter was 0.325 in. (8.26 mm). In experiment 1, the smallest new stimulus used in testing, stimulus 3, was larger (0.36 in., 9.4 mm) than stimulus 5 of experiment 2. Therefore in experiment 1 if the size difference used in testing had been smaller, peak shift might have occurred. These results suggest that peak shift can be found only when the test stimuli are not highly discriminable.

The finding that the blackout method of errorless learning results in slower learning than the traditional method does not indicate that all errorless methods are slower training methods. Indeed several experimenters have reported that when the fading method is used to obtain errorless learning, discriminations that cannot be taught by the traditional method can be conditioned (Moore and Goldiamond, 1964; Sidman and Stoddard, 1967).

The decrease in relational responding for all subjects between the first and second transposition tests was correlated with a shift in the mode of responses back to the S+ value. Terrace (1966b) showed that this shift in mode was an effect of overtraining. He suggested that unreinforced responding to S- is aversive, causing the negative stimulus to take on aversive properties. With continued training, however, the subject no longer responds to the S- and so the S- loses its aversiveness by extinction. If Terrace is correct, the blackout technique may also have aversive properties when the positive and negative stimulus are on the same continuum, and this aversiveness may extinguish with overtraining. Relational responding would therefore only occur when the S- was aversive.

This suggests that a study which employed the fading method to obtain errorless discrimination learning would not find relational responding on transposition tests or peak shift on generalization tests.

The relatively slow learning, peak shift and the observed behavior patterns to S- all suggest that the Lyons' blackout method of "errorless" discrimination learning has more in common with traditional discrimination learning than with errorless discrimination formed through a fading procedure. To respond on the key, a bird orients toward the key and moves its head toward the key and finally strikes the key. With the Lyons' blackout method the time out occurs after the initial components of this response chain but before the final component of striking the key. Thus the early components may be under extinction with all of its consequences including development of aversive properties of S-, peak shift and possibly relational responding. In other words the blackout method may in fact be a traditional extinction method with respect to the behavior precursory to key pecking.

The Lyons' blackout technique is especially promising because it could free the experimenters from the often tedious job of developing a good fading sequence and it can easily be used for any stimulus continuum. It would have important practical implications for programmed instruction. However, if, as we now suggest, this method is in fact based on extinction then it has little to commend it over traditional learning. Additional research should solve this important matter soon.

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Table 1

Stimuli Diameters

Stimulus	Diameter
1 (S-)	0.17 in. (4.3 mm)
2 (S+)	0.27 in. (6.9 mm)
3	0.37 in. (9.4 mm)
4	0.52 in. (13.2 mm)
5	0.74 in. (18.8 mm)
6	1.00 in. (25.4 mm)

Table 2

Sequence of Schedules: Experiment 1

Session	Schedule
1	Magazine Training
2	S+ alternating on the two keys, each response to S+ reinforced.
3	S+ alternating on the two keys, 30 sec. trials, VI 30 sec. schedule of reinforcement, VI 10 sec. intertrial interval.
4-10	Same as above with VI 60 sec. schedule of reinforcement.
11-Criterion	Traditional training method, subjects S-39, S-41 and S-42: S+ and S- trials randomly alternated, S- extinction.
	Errorless training method, subjects S-40, S-43 and S-44: S+ and S- trials randomly alternated; on approaches to the S-, the experimenter darkened the chamber for two sec.
Test 1	First transposition test, stimulus pairs on each trial.
Retrain	Discrimination training as in session 11.
Test 2	Generalization test, only one stimulus present per trial.
Retrain	Discrimination training as in session 11.
Test 3	Second transposition test, stimulus pairs on each trial.

Table 3

Performance to Criterion for Each Subject: Experiment 1

Subject	Method	Days to Criterion	Number of S- Approaches	Number of "Follow Through" Responses	Number of S- Responses	Average Per Sec. Rate of Responses to S+
S-40	Errorless	3	559	276		1.84
S-40	Errorless	2	223	98		1.14
S-44	Errorless	3	670	52		1.70
S-39	Traditional	2			1230	1.28
S-41	Traditional	2			936	1.87
S-42	Errorless to Traditional	7 + 2	2012	503	356	1.95

Table 4

Stimuli Diameters

Stimulus	Diameter
1 (S-)	0.185 in. (4.70 mm)
2	0.220 in. (5.59 mm)
3 (S+)	0.255 in. (6.48 mm)
4	0.290 in. (7.37 mm)
5	0.325 in. (8.26 mm)
6	0.360 in. (9.14 mm)
7	0.395 in. (10.0 mm)
8	0.430 in. (10.9 mm)
9	0.465 in. (11.8 mm)
10	0.500 in. (12.7 mm)

Table 5

Performance to Criterion for Each Subject: Experiment 2

Subject	Method	Days to Criterion	Number of S- Approaches	Number of "Follow Through" Responses	Number of S- Responses	Average Per Sec. Rate of Responses to S+
S-47	Errorless	4	483	144		1.30
S-51	Errorless	7	1018	341		0.73
S-53	Errorless	4	604	88		0.75
S-45	Traditional	3			1695	1.71
S-46	Traditional	3			1688	2.36
S-52	Traditional	4			1771	1.70

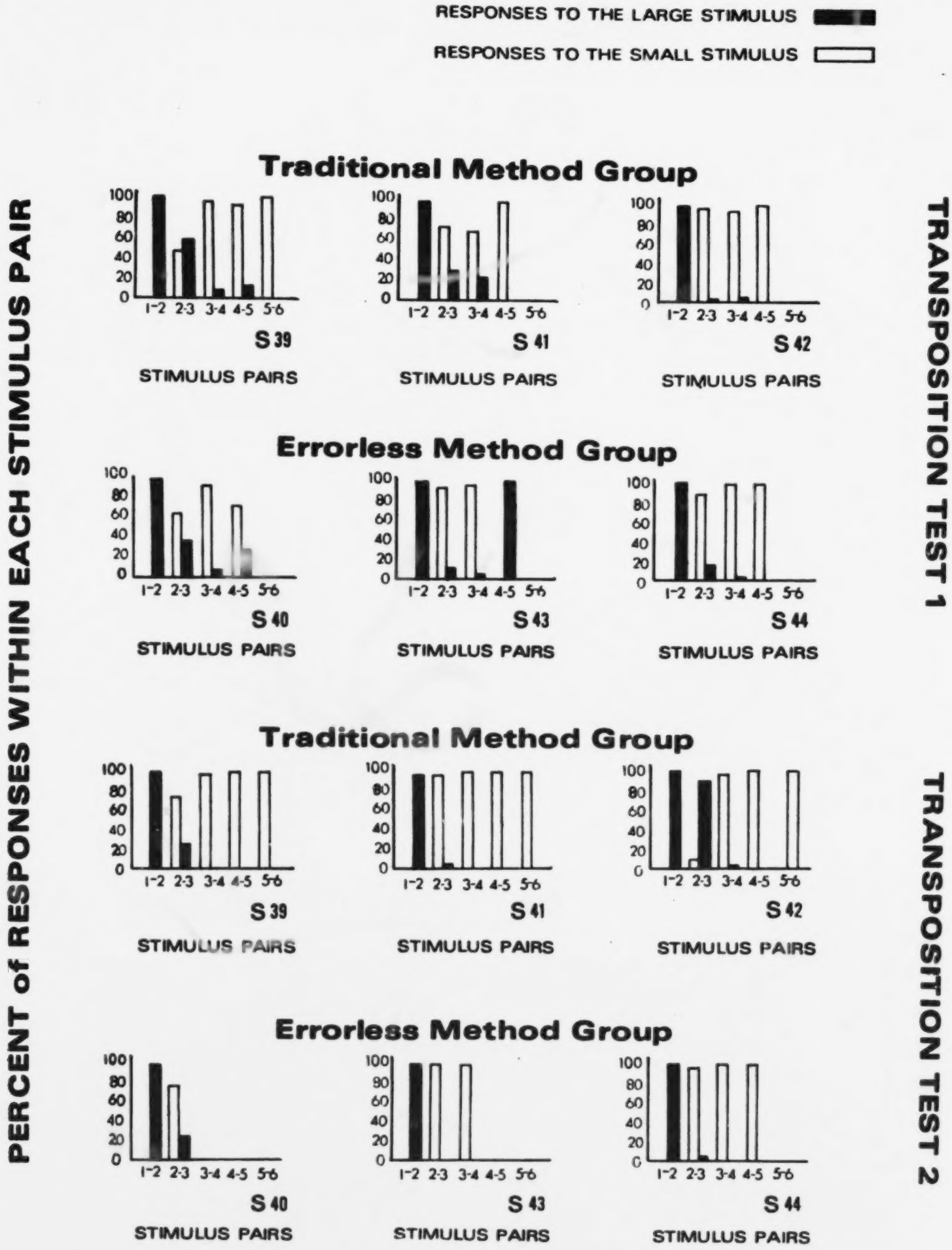

Fig. 1. Percentage of responses to each member of the stimulus pairs in experiment 1.

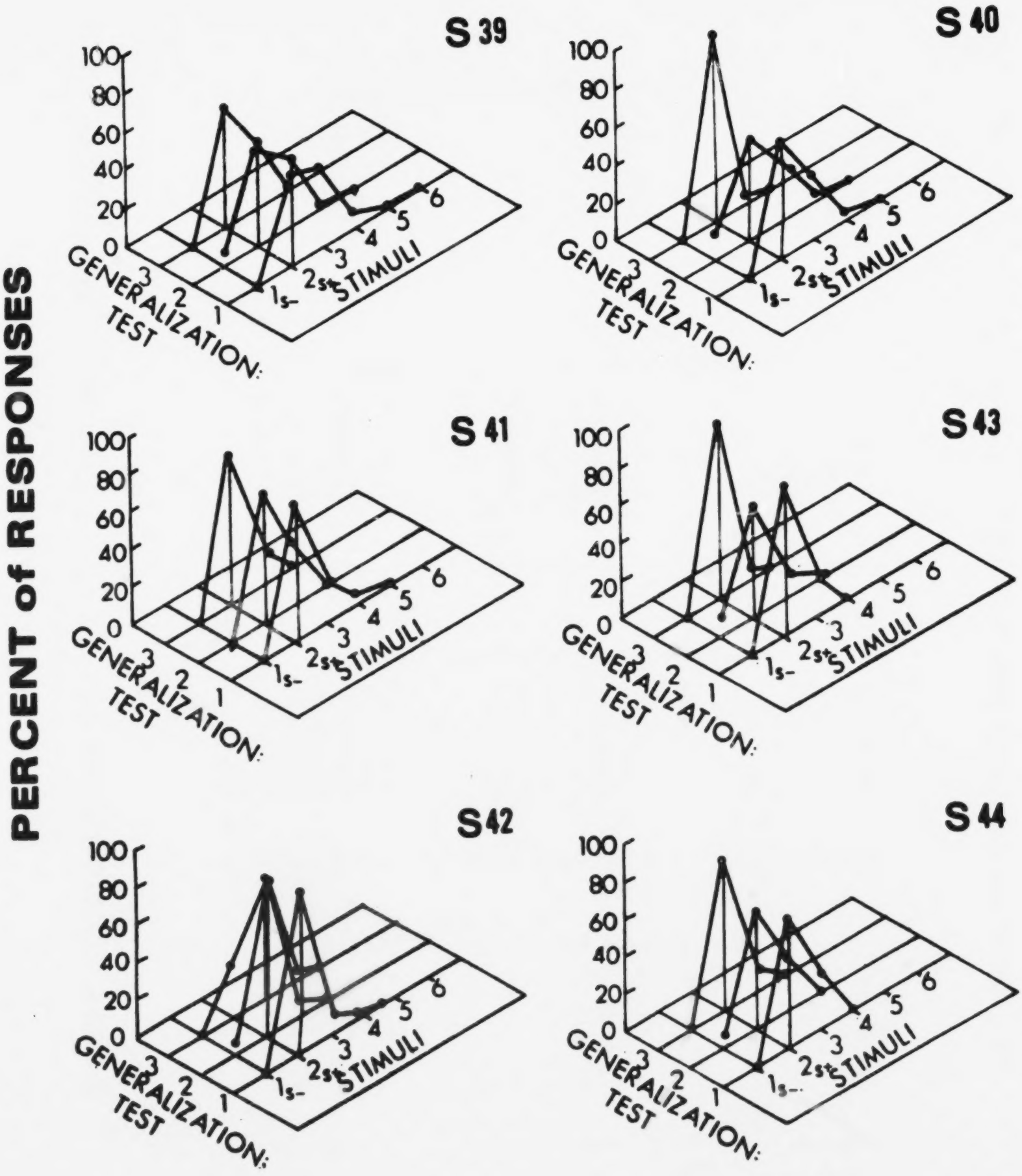

Fig. 2. Percentage of responses to each stimulus for the three tests of experiment 1.

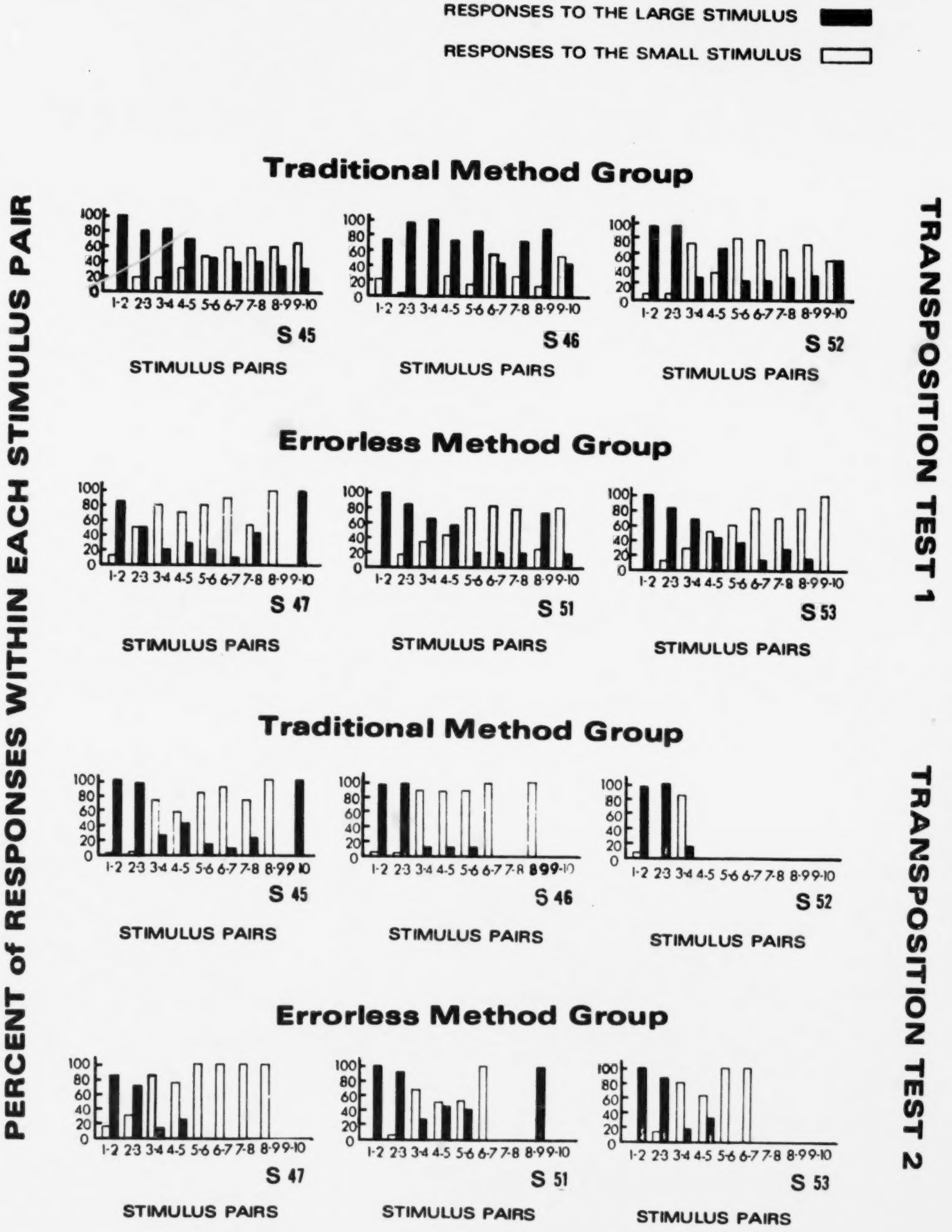

Fig. 3. Percentage of responses to each member of the stimulus pairs in experiment 2.

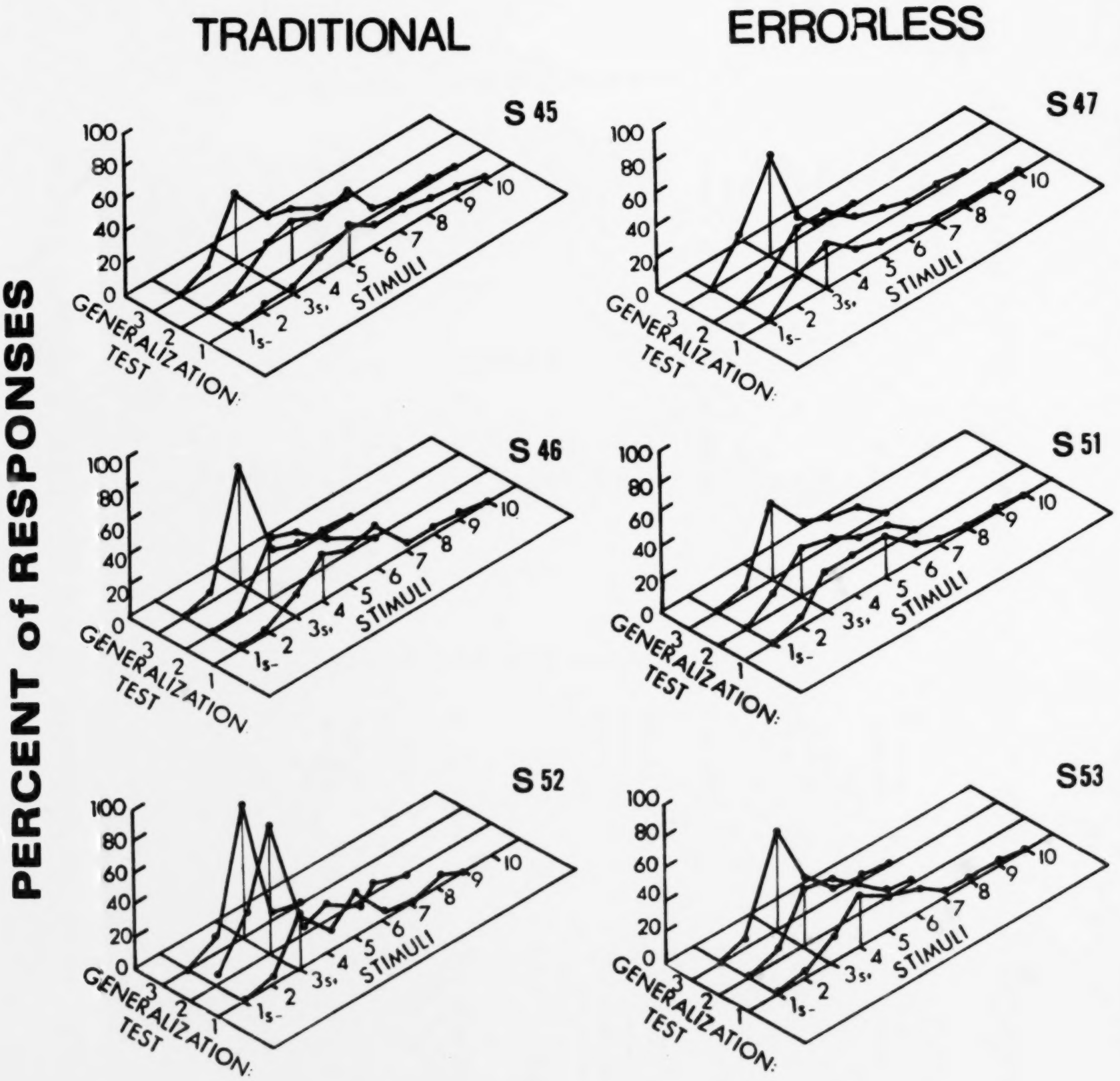

Fig. 4. Percentage of responses to each stimulus for the three tests of experiment 2.